REPORT No. 134

PERFORMANCE OF MAYBACH 300-HORSEPOWER AIRPLANE ENGINE

By S. W. SPARROW
Bureau of Standards

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INTRODUCTION.

This report, which was prepared for the Engineering Division of the Army Air Service and submitted to the National Advisory Committee for Aeronautics for publication, deals with the results of a test made in the altitude chamber of the Bureau of Standards upon a Maybach engine. The engine was submitted by the Engineering Division of the Air Service according to their policy of obtaining reliable measurements of the altitude performance of engines which have proved unusually satisfactory in service, or which embody features of design that appear to be of particular value for altitude work. The test program is not arranged with a view to making measurements under conditions numerous and varied enough to make it possible to predict accurately the performance of the engine under all conditions which may arise. Its aim is rather to measure the performance under typical service conditions in order to determine whether the engine gives sufficient evidence of superiority in any phase of performance to warrant further study.

TESTING OF ENGINE.

The engine tested was No. 2026. It has six vertical water-cooled cylinders with a bore of 6.50 inches, a stroke of 7.09 inches, and a compression ratio of 5.9. A complete description of this type engine is given in Power Plants Report No. 49, of the Engineering Division. In addition, the engine has been described in several automotive journals.[1] It will be noted in these descriptions that the carburetor is unusual in many features of design and these must be borne in mind in interpreting the results. The design is such that all adjustments of air-fuel ratio are effected by a group of rods and levers which simultaneously change the area of the fuel orifice and the areas of the main and a supplementary air passage. This air-fuel ratio control system is interconnected and can not be operated independently of the throttle. Hence, any change in the quality of the charge is accompanied by a change in the quantity of charge.

Tests were made in the altitude chamber of the Bureau of Standards where controlled conditions of temperature and pressure can be made to simulate those of the desired altitude. A description of this chamber and the measuring apparatus is given in Report No. 44, of the National Advisory Committee for Aeronautics.

In all tests a mixture of 20 per cent benzol and 80 per cent X gasoline was used.[2] This addition of benzol was for the purpose of preventing preignition at air densities corresponding to ground level and was used at the other densities to make all results uniform in so far as the fuel was concerned.

Runs were made at engine speeds of 1,000, 1,200, 1,400, and 1,600 r. p. m. at air densities corresponding to ground level and altitudes of 5,000, 10,000, 15,000, 20,000, and 25,000 feet. These runs were made at full power. At the same densities, propeller-load runs were made at speeds of 1,200 and 1,000 r. p. m. The load at these speeds was adjusted to equal that which would be imposed by a propeller so proportioned as to absorb the full power of the engine at

[1] "Aviation," Oct. 15, Nov. 1, Nov. 15, 1918. "Automobile Engineer," September, October 1918. "Automotive Industries," Oct. 31, Nov. 7, 14, 21, 1918.

[2] X gasoline conforms to United States Government specifications for aviation gasoline.

1,400 r. p. m. In selecting these loads, it is assumed that the power required to drive a propeller varies with the cube of the speed and hence the brake horsepower at 1,200 r. p. m.= $\frac{1{,}200^3}{1{,}400^3}\times$ (b. h. p. at 1,400). Friction-horsepower runs were made at all conditions of speed and altitude at which full-load measurements were obtained. At air densities corresponding to ground level and altitudes of 15,000 and 25,000 feet tests were made at various intake air temperatures. Such tests indicate the power changes likely to result from a given change in temperature. Their more important function is to disclose any fault of engine performance that might appear only at certain temperatures.

Results are for the most part presented in the form of curves. Full-load brake-horsepower and brake mean effective pressures are given in figures 1, 2, 3, and 4. It must be remembered that full load does not necessarily mean with wide-open throttle in this engine. As mentioned previously, the carburetor is so constructed that opening the throttle has a twofold effect, the first being to increase the quantity of charge supplied the engine, the second to increase the air-fuel ratio. It was only at air densities corresponding to altitudes higher than 15,000 feet that maximum power was obtained with the throttle fully opened.

Friction-horsepower curves, shown in figures 5 and 6, include one made at ground level density, at part throttle. From this and the one made at full throttle at the same density, the relation of friction horsepower to manifold suction, shown in figure 6, has been determined. Previous experiments justify the assumption of a linear variation in friction over this range of suctions.

The purpose of this curve showing the relation of friction horsepower to manifold suction is to make possible the determination of friction horsepower for the full-load runs in which the throttle was not wide open. In such determinations the first step is to find from the plotted curves the difference between the manifold suction on the power run and that obtained at the same speed and air density at full throttle on the friction run. The next step is to increase the friction horsepower at full throttle by an amount equal to the increase in friction horsepower produced at the same speed at ground level density by the same change in manifold suction. This correction never constituted more than a small percentage of the total friction, and hence extreme care in its computation was unnecessary. From the results obtained at full throttle at the air density corresponding to 5,000 feet, the throttle appears to have been adjusted so that the mixture at 1,400 and 1,600 r. p. m. was considerably leaner than at 1,000 and 1,200 r. p. m. The dash lines in figures 8, 9, 16, and 17 indicate probable values had the air-fuel ratio been the same at all speeds as at 1,000 and 1,200 r. p. m. Full lines represent results as measured.

One feature of engine performance that is of particular interest is the percentage of the power developed at ground level that is obtained at various altitudes. Figures 10 and 11 show this relation at engine speeds of 1,000, 1,200, 1,400, and 1,600 r. p. m. In figure 12 there is a similar comparison between the Liberty 12, Hispano "300," and Maybach at 1,600 r. p. m. The curves are not strictly comparable, inasmuch as the Maybach was tested at a constant air temperature, while the other two engines were tested at temperatures which were different for each density, the lower temperatures occurring at the lower densities. Had all engines been tested under the same temperature conditions, slightly higher percentages would have been obtained with the Liberty and Hispano engines. At an air density of 0.035 the amount of this increase would probably be sufficient to raise the percentage of indicated horsepower from 38 to 40 and that of brake horsepower from 31 to 34.

At air densities corresponding to altitudes up to and including 15,000 feet there was ample carburetor adjustment; that is to say, the engine gave its highest power at throttle positions less than wide open. So small were the differences in specific fuel consumption at these lower altitudes that in some instances bands have been drawn to include all of the results rather than individual curves for each set of conditions. The lower heating value of the fuel used was 18,320 B. t. u. per pound, and the per cent thermal efficiency based on this value may be obtained by dividing 13.87 by the fuel consumption in pounds per horsepower hour.

Figure 14 shows that the specific fuel consumption based on indicated horsepower is comparatively high at air densities of 0.029 and 0.036. Hence, at these densities the high specific fuel consumption in terms of brake horsepower, as given in figure 13, can not be due entirely to low mechanical efficiency. That it arises largely from lack of adequate carburetor compensation is confirmed by the air-fuel ratio curves of figure 18. The erratic nature of these curves may be attributed to the manual adjustment of the mixture ratio up to and including an air density of 0.044. In the conventional carburetor design, where the mixture adjustment changes the rate of gasoline flow but does not seriously affect the rate of air flow, it is difficult to adjust for maximum power with minimum fuel consumption, because a large change in air-fuel ratio produces a comparatively small change in power. Enriching the mixture usually decreases the power less than a similar amount of impoverishment, and the tendency is therefore toward a mixture too rich rather than too lean. In the carburetor used in these tests, an enriching of the mixture is always accompanied by a decrease in the amount of charge received by the engine and hence results in a much greater decrease of power than is the case with the conventional carburetor. When the mixture is made lean the reverse is true, the engine receiving a greater charge and hence sustaining a smaller power decrease. Hence, although this carburetor does not make less difficult the adjusting for maximum power with minimum fuel consumption, it does have the marked advantage that any error in adjustment always tends in the direction of leanness rather than richness. Moreover, it is so designed that maximum power is attained with a leaner mixture than that which would produce maximum power if the same amount of it could be supplied the engine as of the leaner mixture. This makes for high efficiency, since the highest efficiency is always obtained with a leaner mixture than that which gives maximum power.

In the calculations of heat distribution as presented in figure 20, the higher heating value of the fuel, 19,780 B. t. u. per pound, has been used, since in the calorimetric measurement of exhaust heat the water vapor resulting from combustion is condensed. No consideration has been given to the power developed by the combustion of the lubricating oil because of lack of information as to how much of the oil consumed is actually burned on the power stroke.

Figures 23 and 24 show that under propeller loads, reductions in speed produce a rapid decrease in air-fuel ratio and, hence, a rapid increase in specific fuel consumption.

CONCLUSIONS.

From the standpoint of thermal efficiency the full-load performance of the engine is excellent at densities corresponding to altitudes up to and including 15,000 feet. The brake mean effective pressure is rather low even at wide-open throttle. This tends to give a high weight per horsepower, inasmuch as the weight of many engine parts is governed by the size rather than the power of the engine. At part load the thermal efficiency of the engine is low. Judged on a basis of performance the engine's chief claim to interest would appear to lie in the carburetor design, which is largely responsible for its excellent full-load efficiency and for its poor part load efficiency.

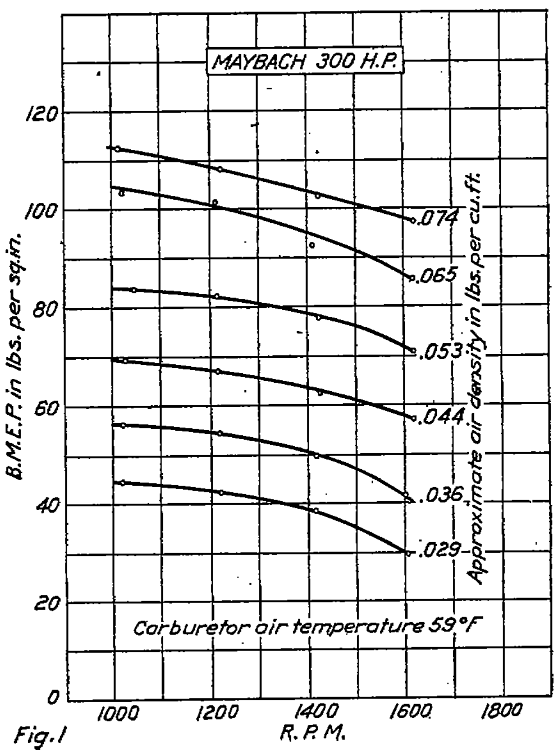


Fig. 1

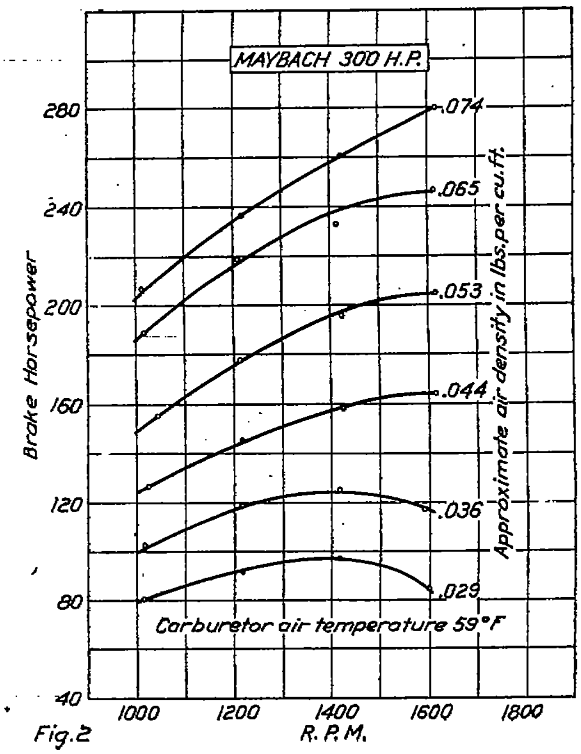


Fig. 2

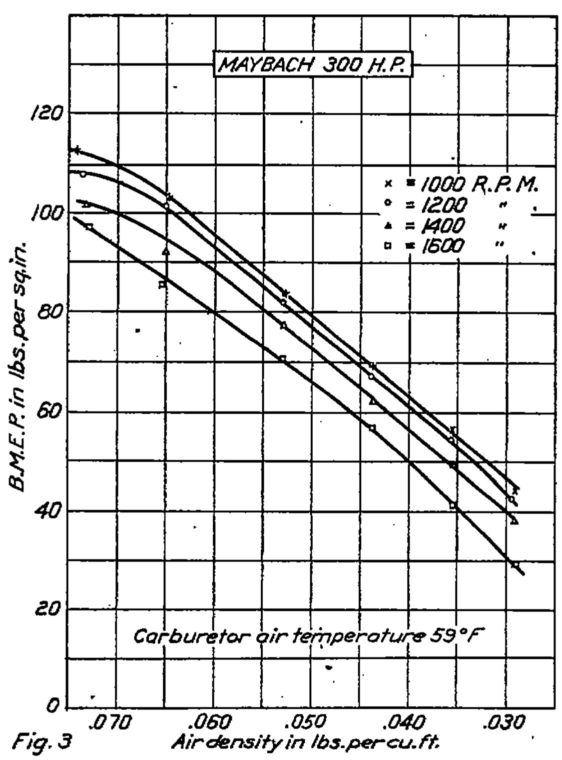


Fig. 3

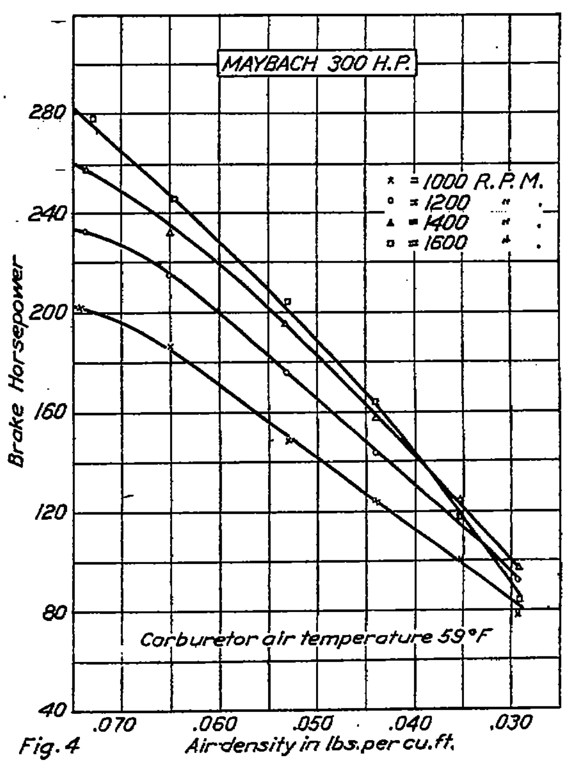


Fig. 4

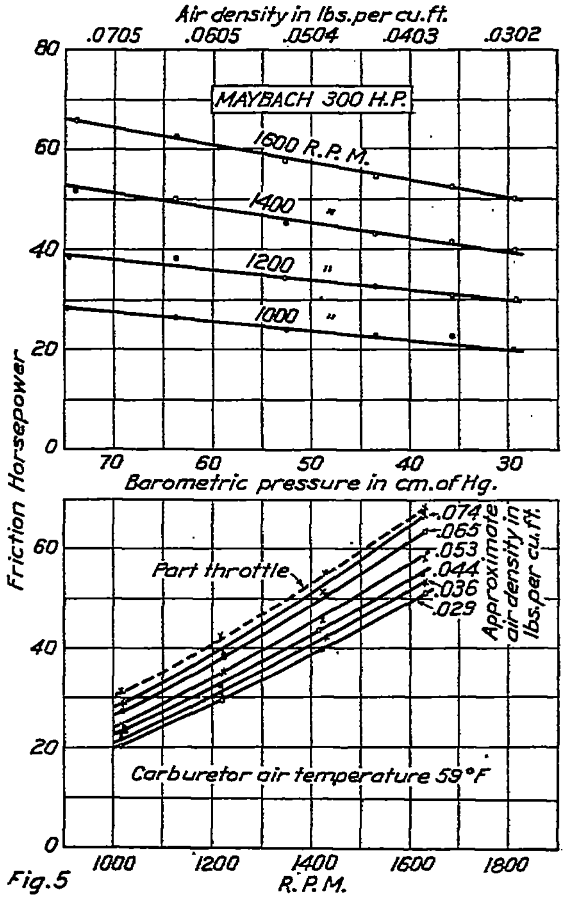


Fig. 5

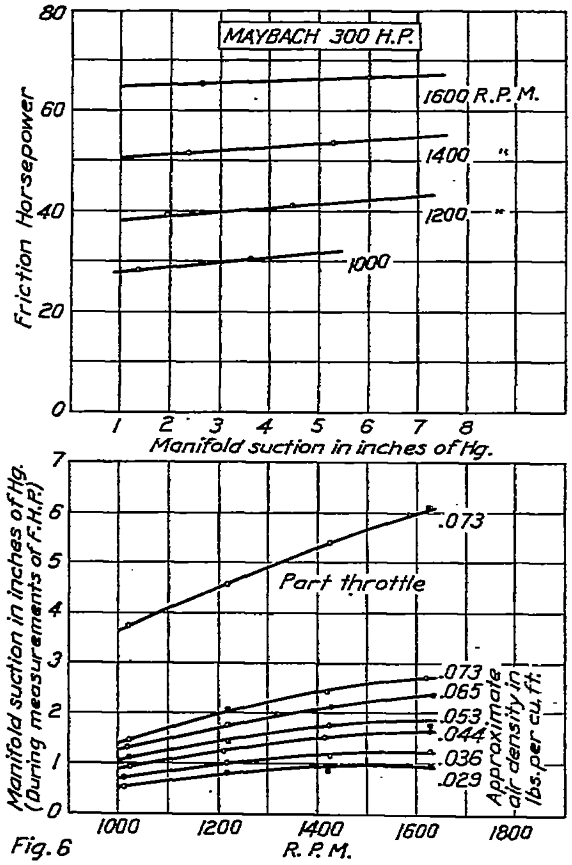


Fig. 6

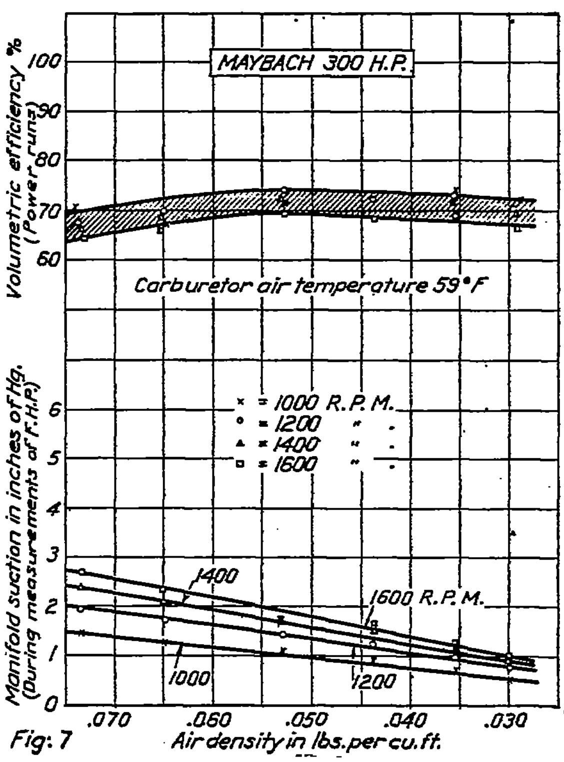


Fig. 7

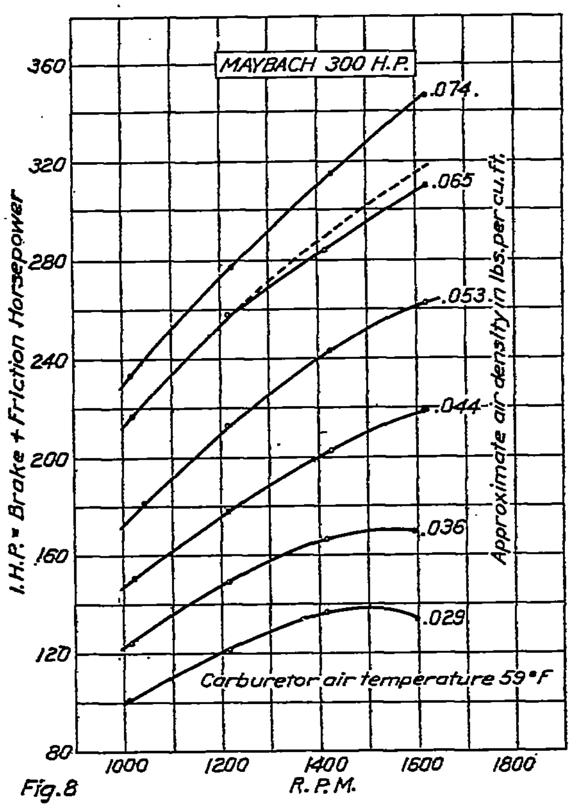


Fig. 8

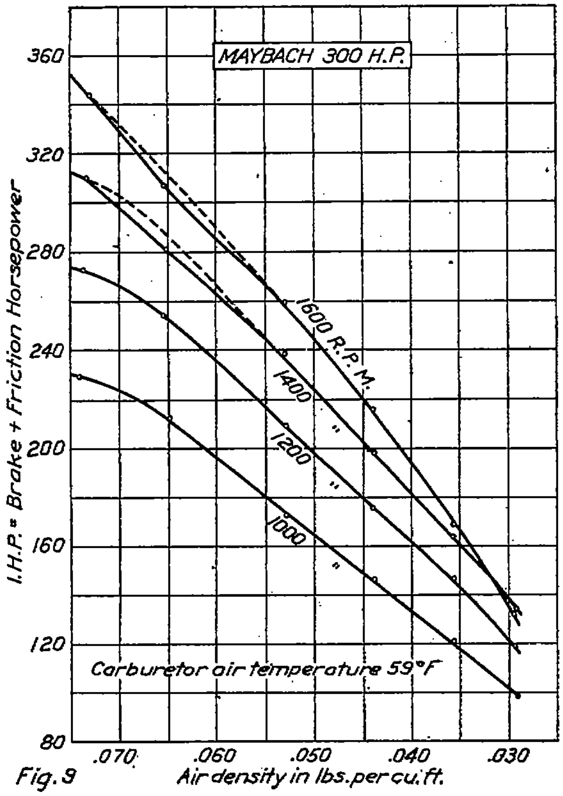


Fig. 9

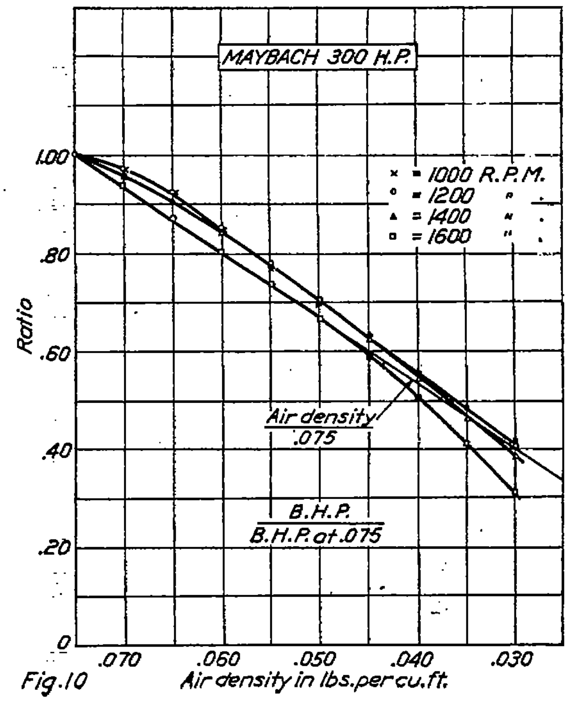


Fig. 10

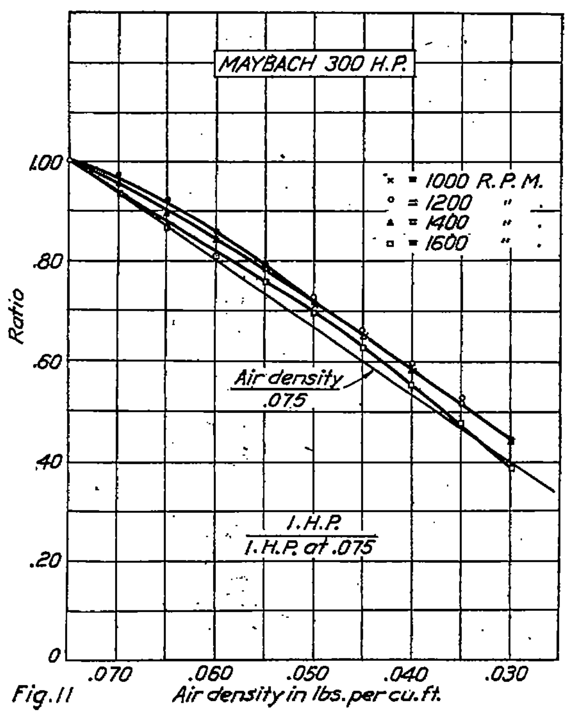


Fig. 11

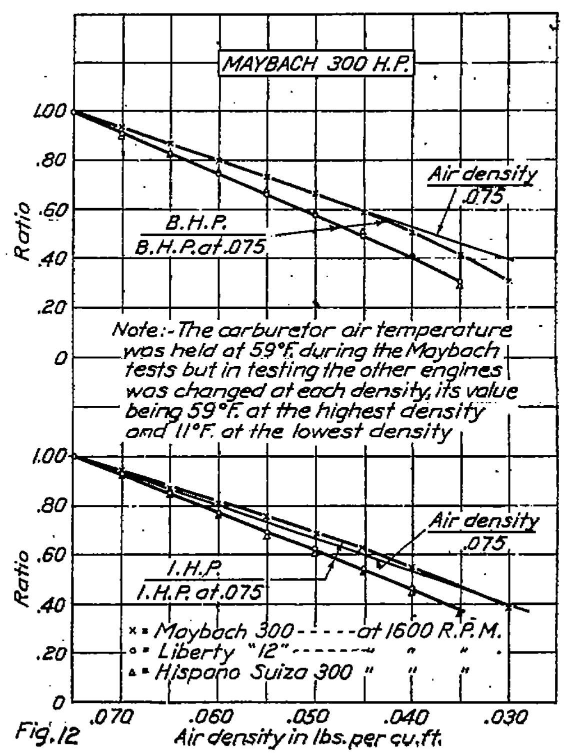


Fig. 12

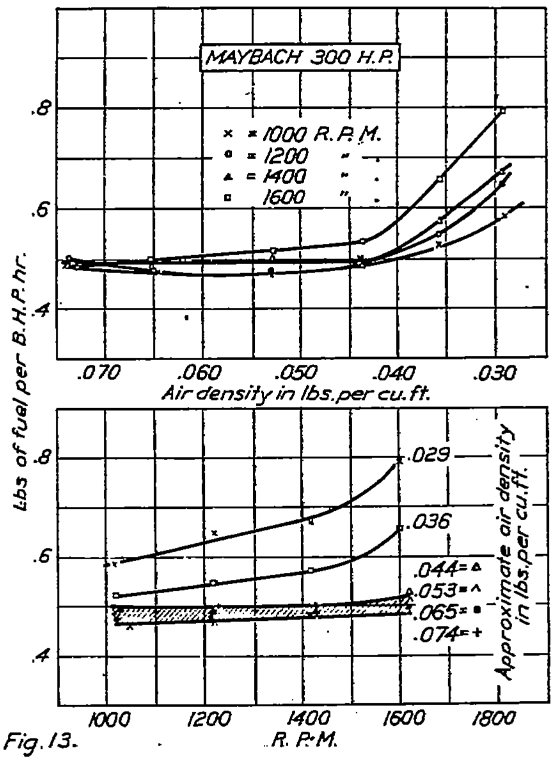


Fig. 13.

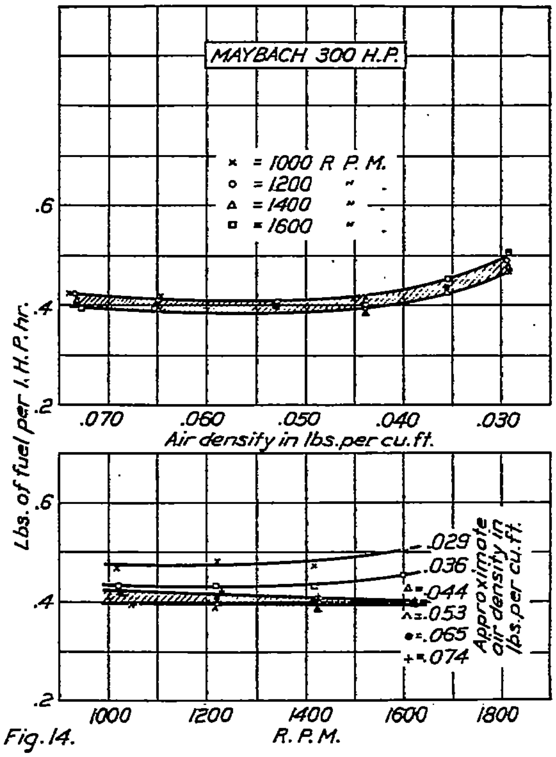


Fig. 14.

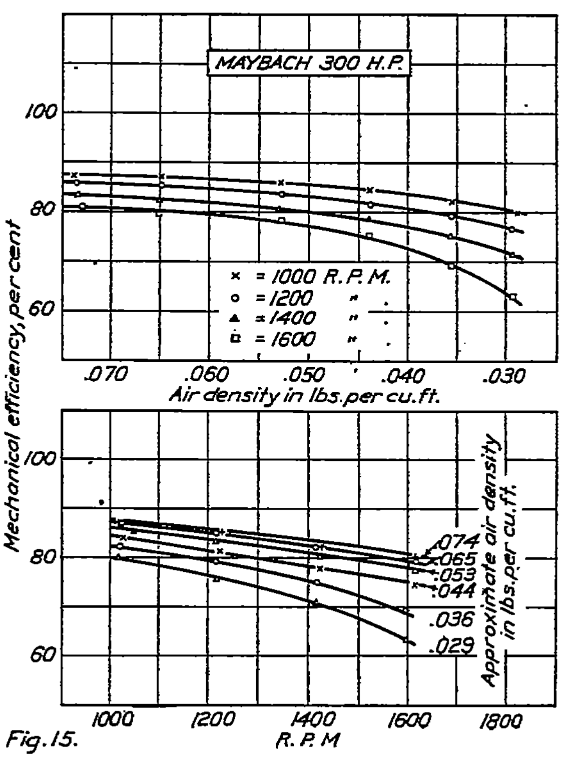
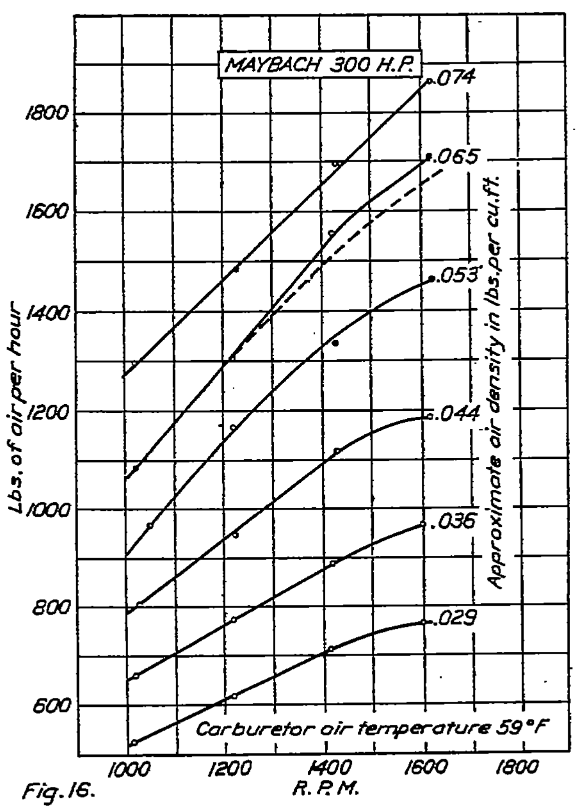


Fig. 15.



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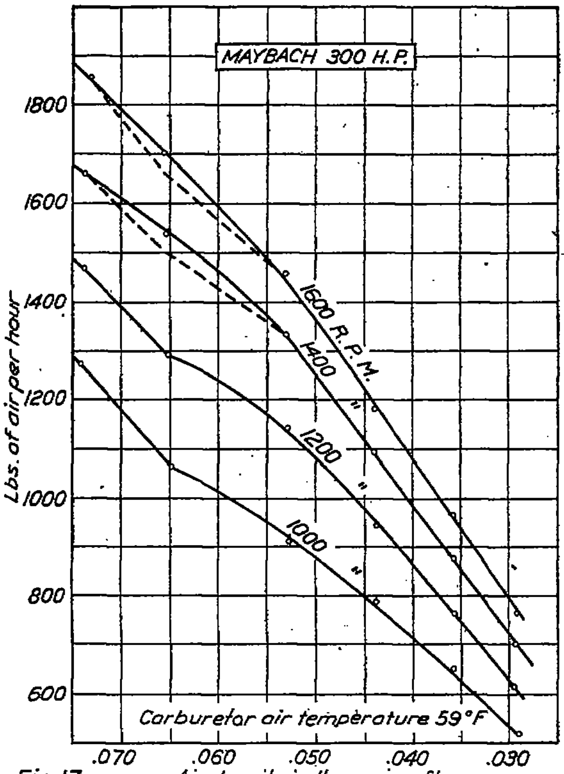

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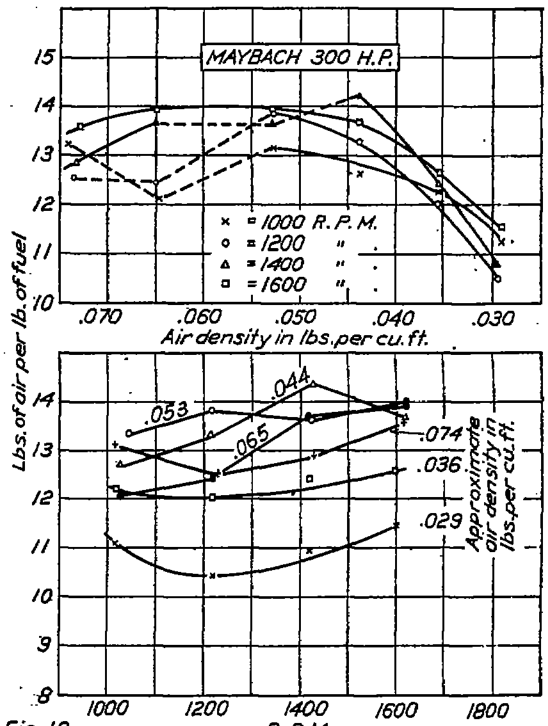
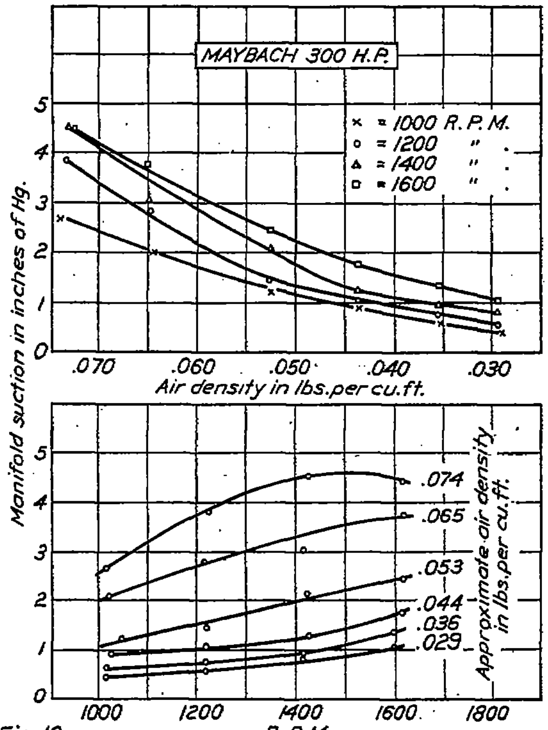


Fig. 18.



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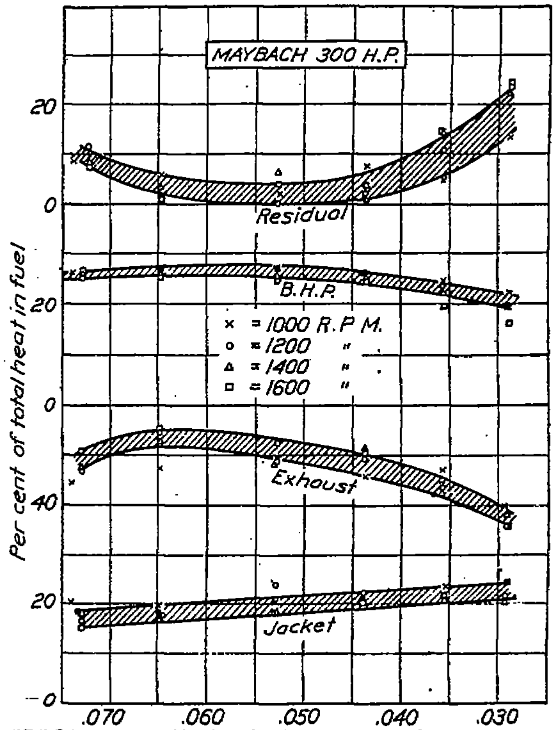
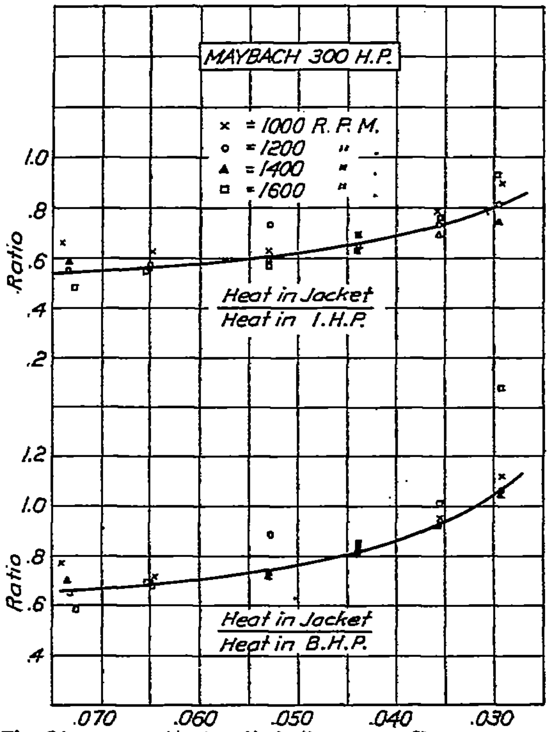


Fig. 20



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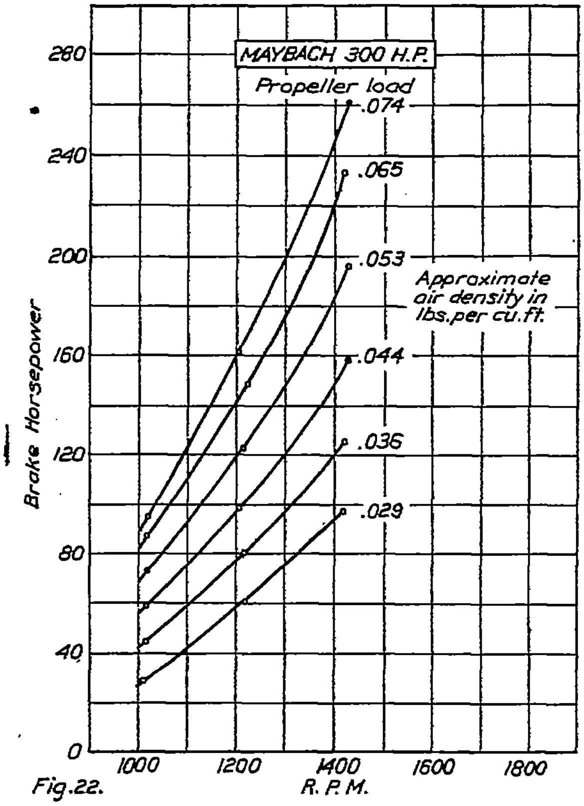

Fig. 22.

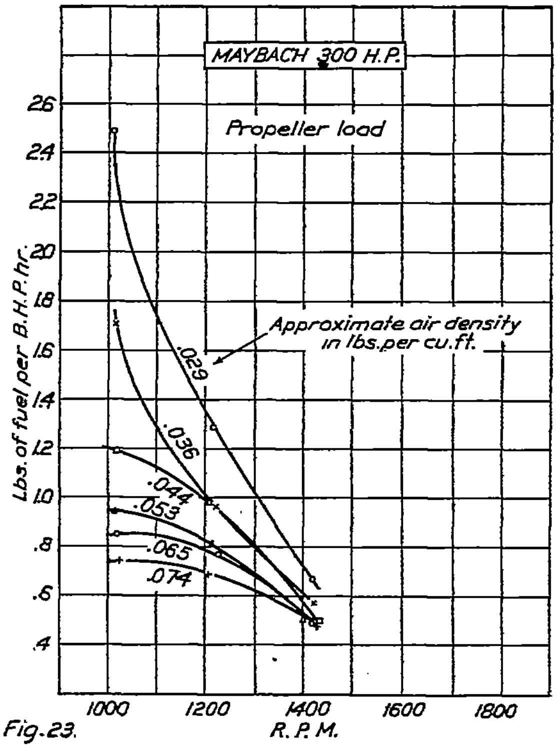

Fig. 23.

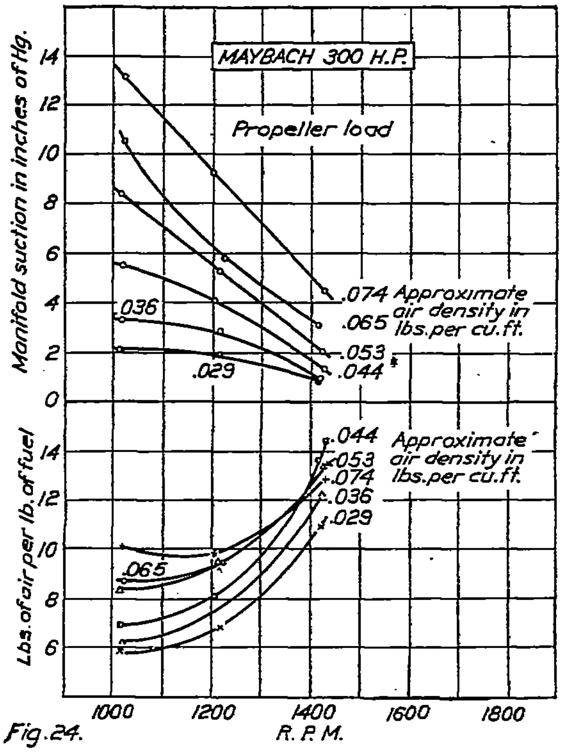

Fig. 24.